Addressing the Bandwidth Demand of Immersive Applications Through NFV in a 5G Network

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Addressing bandwidth concerns in mixed reality applications

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Abstract Augmented and virtual reality technology are expected to become key technological players in the next wave of consumer electronics with potential applications spanning a wide variety of sectors. Yet, there are a number of technological hurdles which need to be addressed. Without speed and computation capability interactivity cannot work. More than often the constrained nature of the mobile device demands are complemented by cloud ones through the use of cloud offloading techniques. With cloud offloading, battery consumption and processing performance problems are translated into sensor data selection and network latency problems. In this context, we focus our study on a network function which could be deployed in a 5G virtualized architecture to alleviate bandwidth requirements of immersive application scenarios. To this end, we rely on a real dataset, providing user-centric metadata on several 4k, 360-degree videos. Different computational methods are proposed and contrasted, evidencing the goodput of the approaches.

Keywords Virtual Reality · Transport Protocol · Virtualization

1 Introduction

2 Introduction

Augmented reality (AR) and virtual reality (VR) have been recognized as important use-cases in the so-called fifth generation (5G) mobile networks, outlining the need for so-called optimized network slices aimed at supporting the stringent latency and bandwidth requirements some of these scenarios embody [**?**].

In the meanwhile, we are witnessing the proliferation of gadgets used to enjoy AR/VR experience along with software libraries used to built customized

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user experiences [?]. Indeed, AR/VR have been brought into different contexts ranging from entertainment to industry or education. As an example, the Pokémon Go era showcased the potentiality of AR technology applied to the gaming domain [?]. In this same domain, we find dedicated VR consoles whereby users enjoy an immersive game play through the aid of VR headsets e.g., [?]. In education, an AR/VR experience allows one user to visit ancient ruins, augment lectures and narration e.g., exploration of the human body and by practising surgery [?,?]. Remote diagnostics, repair and design are some examples of the same technology applied in the industrial domain [?].

While a lot of interesting application scenarios are emerging, we are still at the beginning of what this technological wave could become. This because there are a number of technological issues which must be addressed. In essence, we are not yet at the point where users may interact with dynamic scenes, while on the move. Implementing such type of scenario requires the development and deployment of high performance and lightweight algorithms capable of providing on-device localization, graphics rendering, user interaction support and device-to-cloud communications. Although 5G technology is recognized as a key enabler of AR/VR, commercial deployments of 5G networks are not expected before 2022 while the AR/VR market is expected to flourish in 2020.

In particular, the issues are further exacerbated when considering full-immersive virtual environments. That is the case of streaming 360-degree videos used to achieve a full-immersive visual experience. As the authors in [?] point out, when considering a human fovea of 200 dots, hence 200 pixel per degree, a user field of view (FoV) of 150x120 degrees, a future compression factor of 600, a full motion video at 60 fps would require a 5.2 Gpbs network throughput while adhering to stringent QoE requirements of human perception. Hence, 5G will have a hard time supporting these scenarios in static mobility, let alone scenarios where mobility and wireless artifacts are involved.

In this context, application-driven-networking could be a viable road ahead, employed in order to reach the required efficiency in network resource usage. In this emerging networking paradigm, network functions can be interconnected and chained together forming a co-called service function chain, embodying several optimization's tailored to the dynamics of the scenario at hand [?]. Without loss of generality, one could envision the following series of optimization's which could contribute in alleviating network resource demand in scenarios of bandwidth hungry media while at the same time not impede on latency requirements:

- *FoV-Cut* function: a network function which performs a cut of the 360-degree scene depending on the user(s) FoV. This function once served the user FoV as an input, computes the resulting scene falling encompassing the user(s) FoV, airing parts of it instead of the full video.
- *Fov-Prediction* function: a network function capable of predicting a users' FoV based on historical input, using the outcome to pre-fetch pieces of the scene not yet aired. This function could be employed in times where the network path is idle or not fully utilized i.e., the user is relatively static.

– *Optimized Transport*: considering the presence of heterogeneous flows e.g., video and user FoV, potentially sharing the same path, a dedicated transport layer aimed at guaranteeing their co-existence and QoS level is required. To this end, state-of-the-art proposals such as VoAP, TCP-Wave might be suitable candidates achieving the desired objective [?,?].

All the above optimization's could be provisioned as virtualized network functions orchestrated and managed within an architectural framework having end-to-end visibility on network resources. To this end, comes into help the Network Function Virtualization (NFV) reference architecture, a 5G ingredient conceived as a logically centralized brain capable of a unified resource management [?]. While preserving the general aspect of this study and without loss of generality, we focus our attention on the $FoV - Cut$ function. In this context, we propose different computational methods, contrasting their goodput. To this end, we rely on a publicly available dataset containing user-centric metadata on 360-degree videos. In addition, we discuss a proof-of-concept solution emulating the proposed approach.

The rest of this paper is organized as follows. In Section 3 we provide some background on some of 5G technological ecosystem. Section ?? provides some details of the dataset under scrutiny. Section ?? discusses the different computational methods while Section ?? discusses the obtained result. In Section ?? we propose a proof-of-concept solution emulating the functions behaviour. Finally, Section 7 concludes the article.

3 Background

Differently from the previous generations of mobile networks, the 5G architecture is a service-based architecture (SBA) in which the system functional blocks are implemented as Network Functions (NFs) that expose a set of standardized interfaces to other NFs authorized to interact. NFs are stored in a NF repository in order to discover the services offered by other NFs. This NF based architectural approach supports the concepts of modularity, reusability and self-containment fostered by current network softwarization approaches in order to exploit the advantages of state-of-the-art virtualization technologies.

From a high-level point of view, a 5G network is thus a set of logical network functions, deployed on top of a set of end-to-end physical resources, that need to be dynamically instantiated, interconnected, orchestrated, scaled, migrated and terminated. The main enabling technologies in this vision are:

1. Network Function Virtualization (NFV), i.e. the set of technologies meant to replace physical implementation of network devices and appliances (routers, firewall, ACL, etc..) with software implementation running on legacy multipurpose hardware [?];
2. Software Defined Networking (SDN), i.e. the set of forwarding abstraction, node architectures and configuration protocols to dynamically re-program high speed forwarding devices through external software controllers [?].

The resulting 5G network has then the flexibility to enable Virtual Network Functions (VNFs) across multiple domains and technologies in order to create to create a service-specific network, and this is referred to as Network Slicing.

While current deployments of 5G are not there yet, the design and provisioning of specialized services e.g., an AR/VR slice(s), through the aid of a standardized NFV/SDN architecture and reference points has the positive impact of being 5G-ready.

In the following, we delve into the details of the network function under scrutiny, whose objective is that of alleviating network bandwidth demand. To this end, we discuss different computation methods and contrast their resulting outcome in terms of bandwidth saved.

4 Related Work

5 Proposal

6 Experimental Analysis

7 Conclusion

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